SPins IN Semiconductors

Dr. Stuart A. Wolf

Spins in Semiconductors

Objective

Create a revolutionary new class of semiconductor electronics based on the spin degree of freedom of the electron in addition to, or in place of, the charge

In March of 1959, Richard Feynman challenged his listeners to build, ***"computers with wires no wider than 100 atoms, a microscope that could view individual atoms, machines that could manipulate atoms 1 by 1, and circuits involving quantized energy levels or the interactions of quantized spins."***

Richard Feynman - "There's Plenty of Room at the Bottom"

1959 Annual Meeting of the American Physical Society

Rationale for Spintronics

Conventional Electronics → Charge

- Based on number of charges and their energy →
- Performance limited in speed and dissipation

Spintronics → Spin

- Based on direction of spin and spin coupling
- Capable of much higher speed at very low power

Motivation

Two recent discoveries

- *A room temperature, optically induced, very long lived quantum coherent spin state in semiconductors and quantum dots that responds at Terahertz with no dissipation and can be transported by small electric fields (UCSB, 1997-1999).*
- *Ferromagnetism in semiconducting GaMnAs at 120K (Sendai, Japan 1998)*

Will lead to revolutionary advances in 21st Century photonics and electronics such as:

- *Very high performance optical encoders and decoders*
- *Very fast, very dense memory and logic at extremely low power*
- *Spin quantum devices like Spin-FETs, Spin LEDs and Spin RTDs*
- ***Quantum computing in conventional semiconductors at room temperature***
- *Many other applications that we can’t even envision now*

Expected SPINS R & D

Understand and control spin effects in semiconductors

Since spin effects in semiconductors are largely unexplored

- *Explore ways to raise Curie temperature of magnetic semiconductors*
- *Explore optical and transport properties of semiconductors which offer new spin dependent avenues*
- *Understand and control interface effects and spin transport across semiconductor interfaces*
- *Control spin polarized carrier localization*
- *Control spin polarized carrier densities*
- *Control spin lifetimes and mobilities*
- *Explore issues in controlling spin effects in quantum dots and arrays of quantum dots*

Exploit the unique spin effects in semiconductors

- *Demonstrate all semiconductor spin quantum devices*
- *Demonstate teraHertz spin coherent optical devices*
- *Demonstrate high speed, low power, spin logic and spin*

Areas of Program Concentration

- **Quantum Spin Electronics**
  - *Tunneling/transport of quantum confined spin states: natural frequency scale given by spin splitting: GHz-THz*
  - *Spin dependent resonant tunneling devices and spin filtering*
  - *Spin FETs ("spin gating")*
  - *Spin LEDs, electroluminescent devices, and spin lasers*
- **Coherent Spin Electronics**
  - *Optically generated coherent spin states and coherent control of propagating spin information - optical encoders and decoders*
  - *Directly generated coherent spin state and coherent control of propagating spin information*
- **Quantum Information Processing**
  - *Qubits using coherent spin states*
  - *Spin based quantum networks*

Areas out of SPINS focus

- *structures incorporating non-semiconducting layers except to provide a bias field*
- *GMR devices*
- *magnetic oxides*
- *non-spin based quantum information systems*

Tentative Schedule

- *SPINS Pre BAA Workshop January 5-7, 2000*
- *SPINS BAA - February 2000 CBD*
- *Suggested Abstract (White Paper) Submission March 15, 2000*
- *Proposals by invitation*- first award selections April through June 2000*
- *Final abstract deadline December 31, 2000*
- *Proposals by invitation must be received by February 2001*
- *BAA closes February 2001*
- *Second awards -March through June 2001*

* *Proposals will be accepted and evaluated at any time before 2/20*